

REVIEW

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Omics-based molecular techniques in oral pathology centred cancer: prospect and challenges in Africa

Henry A. Adeola^{1,2,3*}, Olujide O. Soyele⁴, Anthonio O. Adefuye⁵, Sikiru A. Jimoh⁶ and Azeez Butali⁷

Abstract

Background: The completion of the human genome project and the accomplished milestones in the human proteome project; as well as the progress made so far in computational bioinformatics and “big data” processing have contributed immensely to individualized/personalized medicine in the developed world.

Main body: At the dawn of precision medicine, various omics-based therapies and bioengineering can now be applied accurately for the diagnosis, prognosis, treatment, and risk stratification of cancer in a manner that was hitherto not thought possible. The widespread introduction of genomics and other omics-based approaches into the postgraduate training curriculum of diverse medical and dental specialties, including pathology has improved the proficiency of practitioners in the use of novel molecular signatures in patient management. In addition, intricate details about disease disparity among different human populations are beginning to emerge. This would facilitate the use of tailor-made novel theranostic methods based on emerging molecular evidences.

Conclusion: In this review, we examined the challenges and prospects of using currently available omics-based technologies *vis-à-vis* oral pathology as well as prompt cancer diagnosis and treatment in a resource limited setting.

Keywords: Omics-based, Molecular, Developing world, Oral pathology, Challenges

Background

As the field of oral pathology expands in Africa, currently emerging omics-based molecular techniques are, in principle, poised to improve the oral disease diagnosis and treatment [1–4]. Despite the vast ground covered by the advances in molecular and omics-based technologies in the developed world, there remains a gap in the uptake and application of these methods in developing countries due to existing militating factors. In order for Africa not be left behind in all these highly beneficial technologies, innovation and maximization of the existing infrastructure is highly required. A sine qua non to research and innovative discoveries is good record keeping; which remains sub-optimally practiced

in most developing economies [5–9]. For example, it has been historically recorded that two previous presidents of the United States of America (Ulysses Simpson Grant & Stephen Grover Cleveland) were diagnosed with oral cancer [10, 11]; however such information is lacking on how many African presidents have had oral cancer in the past. In fact, history has it that some celebrities like Sigmund Freud, the father of modern psycho-analysis; Giacomo Puccini, a famous opera composer; and Sammy Davis Jr., a leading entertainer, died of head and neck cancer [11].

Accurate capture of disease burden in Africa would provide impetus for addressing prevalent early diagnosis and treatment monitoring bottlenecks. The emergence of high throughput omics based sciences in the post genomic era concomitantly attracts the application of computational biology and bioinformatics to elucidate various omics based data [4, 12–14]. Most challenges preventing the implementation of omics-based molecular

*Correspondence: henry.adeola@uct.ac.za

¹ Department of Oral and Maxillofacial Pathology, Faculty of Dentistry, University of the Western Cape and Tygerberg Hospital, Cape Town, South Africa

Full list of author information is available at the end of the article

approaches in routine diagnostic oral pathology in Africa are human resources and infrastructure. Low educational levels; lack of disease registries; poor funding and fiscal policies; lack of biospecimen repositories; and political unrests, inter alia; have significantly impeded research activities in many countries in Africa [15, 16].

This paper focuses on emerging omics-based techniques and their diagnostic and therapeutic potentials and challenges in the context of a resource limited setting.

Main text

Historical perspectives and general diagnostic challenges

Basic biomedical laboratory sciences provides the scientific foundation of clinical practice and supports the use of novel scientific discoveries to justify clinical decision making [17]. However, there remains widespread disconnect between clinicians and basic medical scientists [18–21]. Granted the importance of the art of medicine and clinical practice [22], there is a significant necessity to embrace evidence based science in the era of precision medicine. This point was alluded to over a century ago by the Flexner Report of 1910 [23], which was employed to transform the medical education model in America by establishing integrated biomedical training systems as the gold standard. A shortage of needed infrastructure and manpower has fixated a significant proportion of medical research efforts in Africa on bedside practice; albeit medical practice from ancient Egyptian papyri has been documented for various ailments as early as around 2000 B.C [24–28]. Indeed, evidence of various primary and metastatic cancers has been found by paleopathological and archeological examination of Egyptian mummies [29–34]. Despite the antiquity of medical practice in Africa relative to other regions of the world, there still exists a paucity of application of novel omics-based approaches to routine diagnostic medical sciences.

Inequalities in social determinants of health in low and middle income countries such as those in sub-Saharan Africa constitutes a huge challenge to health care access [35–42]. In addition, there are ample evidences of the existence of ethnic-based disparities in health risks profile in many countries [43–47]. The prospect of using omics-based techniques under such daunting conditions in resource-limited settings is dismal. To set up the right atmosphere for routine diagnostic and therapeutic application of these merging omics-based techniques, systems have to be instituted to address these prevalent disparities in healthcare practice and access in sub-Saharan Africa.

Globally, these are interesting times to apply omics technologies in order to improve human health.

Unfortunately, the African continent is way behind in terms of the financial and institutional commitment required to successfully implement a genomics program for research and clinical use. Genomics is a multi-million dollar endeavor with far reaching implications for a healthy and productive continent [48]. It will unravel health risk, accelerate drug discoveries and motivate lifestyles [49, 50]. Of the sub-Sahara African nations, only South Africa is investing in genomics technologies despite the success stories reported in developed countries around the world. For instance, Nigeria is a country of about 200 million people and there is no genome center despite the training and collaborative opportunities presented through the Human Heredity and Health in Africa (H3Africa) Initiative (h3africa.org/) [51], which facilitates genomic researches and manpower development across Africa. Other factors that discourage the application of molecular research and emerging omics-based techniques to routine diagnostic oral pathology practice in Africa includes: poor access to research journals and conferences [52]; lack of needed skilled manpower [53, 54]; oral pathologist-to-population ratio (including workload and interest) [53, 55]; lack of well-equipped infrastructure such as laboratories and clinics [56–58]; poor internet facilities [59]; unstable electricity/power supply [60]; unfavorable health policies [61–63]; poor collaborative team science [64, 65]; knowledge gaps/educational levels [66–68]; war/local unrest [69]; lack of disease registries [70]; data/record gap in hospitals units [70, 71]; and religious/cultural beliefs [72], inter alia.

Molecular diagnostic challenges

The mortality rate of oral cancer is extremely challenging and depends mainly on the staging of disease at diagnosis and commencement of treatment. Even, though the 5-year survival rate for first stage oral cancer cases can be as high as 80%, the 5-year survival rate for advanced stages (III/IV) are dismally low (20%); Up to 50% of oral cancer cases globally are only detected in late stages [73]. Hence the use of emerging diagnostic approaches to improve early diagnosis and prompt commencement of treatment is key in reducing the high mortality of oral cancer.

A fundamental goal of surgical pathology is to distinguish benign lesions from malignant ones [74, 75]. It is also equally important to be able to differentiate between indolent and aggressive tumors [76]. The use of hematoxylin and eosin (H&E) staining as well as the use of various special stains; backed with good clinicopathologic acumen, has partly improved the diagnosis of disease, albeit this is sometimes with limited diagnostic accuracy [77, 78]. The introduction of immunohistochemistry into

diagnostic pathology significantly improved the confirmation of diagnoses, where morphological differential diagnosis using H&E presented a dilemma. However, immunohistochemistry has been cautiously used and interpreted after its limitations (such as variable antibody reactivity, background staining, poor quantitation, and subjective interpretation) became apparent [78–85]. Another layer of complexity is added to the diagnostic dilemma by intratumour heterogeneity and inter-biopsy heterogeneity, which presupposes that multiple cancer molecular signals can be detected in various sampled regions [86, 87]. This alludes to the notion that molecular classification of disease may be complimentary and in some situations more important than conventional histopathological diagnosis based on H&E staining [88–92]. The advent of various omics based molecular approaches as described hereafter, can potentially improve the diagnosis and monitoring of disease, particularly in the diagnostic grey areas. The benefit of using multiple high throughput techniques in a complementary and integrated manner would no doubt benefit personalized/precision medicine and the field of diagnostic oral pathology immensely (Fig. 1).

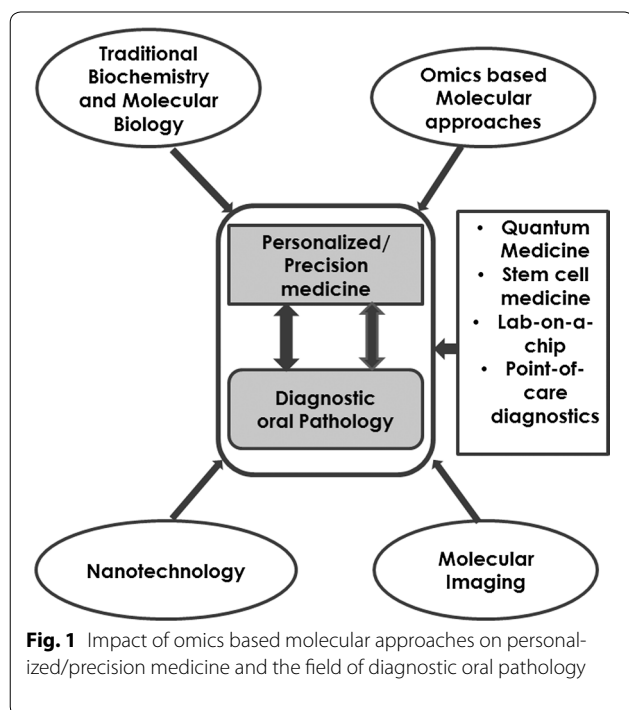
Current and future molecular approaches

The field of molecular biology has undergone significant evolution in the post-genomic era [93–97]. With the emergence of omics-based approaches, research capabilities have expanded from low to medium throughput biochemistry, to interrogation of the full complement of

biomolecules in a high throughput manner. Further, biological molecule have now been characterized in a manner that was hitherto not possible [97]. A few relevant high throughput omics based methods are described hereafter as they relate to the field of oral pathology and cancer.

Traditional biochemistry/molecular biology

To improve the field of molecular medicine, traditional biochemistry has employed various approaches such as: electrophoresis; Western, Northern, and Southern—blotting techniques for protein, RNA and DNA respectively [98]; enzyme-linked immunosorbent assay (ELISA) [99]; gene silencing and RNA interference [100]; gene cloning [101]; conventional and real-time qualitative polymerase chain reaction (PCR) [102]; karyotyping & fluorescence in situ hybridization (FISH) [103]; Comparative genomic hybridization (CGH) [104]; and chromosomal/cytogenetic analysis [105]. However, many of these techniques are limited because they are low to medium throughput in their capabilities. These techniques have benefitted the field of oral pathology by enabling the identification of molecular markers of various diseases. For example, cytogenetic alterations such as copy number gain of 16q, 8q and loss 3p, 8p, 9p, 4q, 5q, 13q have been found to be biomarkers for premalignant oral lesions; while copy number gain of 3q, 8q, 9q, 20q, 7p, 11q13, 5p and copy number loss of 3p, 9q, 21q, 5q, 13q, 18q, 8p have been found to characterize oral squamous cell carcinoma [106–109]. Molecular alterations such as microsatellite instability (MSI), abnormal mismatch repair protein (MMR) proteins MLH1, PMS2, MSH2, MSH6, and loss of heterozygosity (LOH) of 9p21, 3p14 have been found to characterize premalignant oral lesions [106–108, 110, 111]; while perturbation of *p53*, *EGFR/STAT*, *COX-2*, *NF-κB*, *VEGF*, *TGF-β/Ras* pathways have been found in oral squamous cell carcinoma [112–114]. Identified potential biomarkers of metastatic oral squamous cell carcinoma includes E-cadherin, integrins, matrix metalloproteinases (MMPs), IL-8, chemokine receptor 7 and *EGFR* [111]. Various fusion oncogenes have been used as potential biomarkers of salivary gland tumours; such as *MYB-NF1B* t(6:9)(q22-23:p23-24) for Adenoid cystic carcinoma [115]; *CRTC1-MAML2* t(11:19)(q21-22:p13) for low or intermediate grade Mucoepidermoid carcinoma [116]; *ETV6-NTRK3* for Mammary analogue secretory Carcinoma [116, 117]; *PLAG & HMGA2* for Pleomorphic adenoma [118, 119]; *EWSR1-POU5F1* t(6:22)(p21:q12) for high grade Mucopidermoid carcinoma [116]; *EWSR1-ATF1* t(12:22)(q15:q12) for low grade hyalinizing clear cell carcinoma [120]; *NUT-BRD4* t(15:19)(q14:p13.1) for NUT midline



carcinoma [121, 122]; and *MECT1-MAML2* for low grade Mucoepidermoid carcinoma [123]. Considering the impact of tradition molecular biology advances on diagnosis of tumors in the head and neck region, it is plausible that emerging high throughput omics based techniques would even bring greater breakthroughs to diagnostic oral pathology practice.

Omics based approaches

Prior to the completion of the human genome project (which costed billions of dollars and lasted over a decade), only short fragments of DNA could be sequenced using methods such as polymerase chain reaction and hybrid capture [124, 125]. However, with the advent of massive parallel sequencing (also known as Next Generation Sequencing), millions of DNA fragments can now be sequenced even without prior knowledge of the sequence [124]. With an exponential reduction in the cost of sequencing, Next Generation Sequencing (NGS) has improved the utility of various omics field in understanding disease specific genomes [125].

The field of genomics and sequencing also owes its huge success to the development of the array technologies, which were initially fabricated for high throughput genomic interrogate the transcriptional levels of thousands of genes in a single experiment [126, 127]. This technology has made it possible to evaluate pathophysiological gene expression patterns in cells and tissues; as well as to identify drug targets in tissues [126]. Different types of arrays and their application for various biological functions have been discussed in details elsewhere [126–128].

In addition, emerging technological advances have provided the unique opportunity to interrogate biological and genomic complexity to the single-cell resolution. This potentially provides high throughput omics based data which helps to delineate tissue heterogeneity from a bulk population of cells; as well as diversity in complex microbial ecosystems [129]. Although technically challenging, single cell technology has been applied both to genomic and epigenomic analyses of diseases [129, 130]; as well as to drug discovery and development [131].

In tandem with the ever-increasing amount of data generated from high throughput data, a great number of omics fields have emerged [132]. These omics fields have provided access to systems level interpretation of molecular processes. However these techniques requires robust bioinformatics and computational infrastructure to de-convolute and integrate the emerging data for clinical utility [14]. The -omics suffix indicate the analysis of the full complement of a specific biomolecule; as well as its characterization, interaction or analysis [133]. For example, the measurement of the full complement

of protein in a cell, tissue, body fluid, or any biological system is known as proteomics; and this analogy applied to all other biomolecules such as lipids (lipidomics), genes (genomics), gene transcripts (transcriptomics), metabolites (metabolomics), etc. It has been notably demonstrated by Garcia et al. [134], that such omics based techniques would benefit personalized oral healthcare immensely. Examples of promising application of different omics based approaches are described below:

Genomics Genomics techniques provide a genome-wide access to genetic information and presents a robust opportunity to interrogate cancer biology in a high throughput manner. Genomics information have been used to develop databases that have enhanced our knowledge of the cancer genome expression greatly [135]. Although, genomics has attained moderate success in target oncogene and tumor suppressor gene identification; there remains significant challenges in the transformation of these targets into therapies that would improve cancer patient management [136]. Application of genomics to oral cancer diagnosis in diagnostic oral pathology would be greatly improved by advances in the field of dental and craniofacial informatics [137]. Genomic alterations have been identified for leukoplakia as well as in the process of sequential oral tumorigenesis [138]; providing molecular information that were hitherto unavailable.

Transcriptomics Differential transcriptomics profiling of oropharyngeal cancers based on human papilloma virus (HPV) status has been shown to provide reliable molecular signature to stratify these subtypes of head and neck cancer [139]. Thus permitting high throughput analyses of gene transcript and drawing of biological inferences on HPV-related oral cancer.

Genome-wide association studies (GWAS) Genome-wide association studies (GWAS) is an unbiased statistical approach used to identify common single nucleotide polymorphisms across the genome that are associated with complex traits. Since the early 2000s when it was first used, there have been over 2000 published GWAS studies [140]. The success of GWAS is largely dependent on the coverage of the genotyping panel, the minor allele frequency of SNPs in the investigated population and on clearly defined phenotypes. GWAS has been used to identify many novel susceptibility loci for complex traits including oral cancers [141].

Next generation sequencing (NGS) Deep sequencing, massively paralleled sequencing or next generation sequencing (NGS) is a novel DNA or RNA sequencing technology that has transformed genomic research

[142]. As opposed to the Sanger sequencing, this is a high throughput method that can be used to sequence the complete human genome within a day [143]. Significant progress in the sequencing research has led to a reduction in its per megabase cost, number of produced sequence reads per run as well as the genome diversity coverage; which helps to adequately elucidate complex phenotypes of diseases [142, 144]. NGS has been applied to understand oncogenic mutations in oral diseases such as ameloblastomas [145, 146]. Using this method, it was discovered that mutations in the *SMO* gene encoding smoothened protein was commoner in maxillary ameloblastomas, while *BRAF V600E* mutations were commoner in mandibular ameloblastomas [145]. This has far reaching implications for the application of personalized medicine to the management of ameloblastomas [146]. Molecular heterogeneity in head and neck cancers has also been elucidated using NGS methods [147].

Whole exome sequencing (WES) There is an increasing confidence in our ability to understand the impact of identified coding variations. In addition, we are able to sequencing the entire protein coding regions in the genome also known as exome sequencing. Therefore, exome sequencing appears to be a promising omics tool for the rapid identification of functional variations. These thus provide an opportunity for small molecule development through pharmacogenomics and also serve as information for counselling to at-risk families with diseases. In recent times, exome sequencing was used to identify novel oral cancer genes and loci [148–151].

Epigenomics The study of stable and often heritable changes in gene expression patterns that are not caused by changes in the DNA sequence is known as epigenetics [152]. Two of the most well characterized epigenetic alterations are histone modification and DNA methylation [153]. Beyond the genome, the complete set of epigenetic modifications to the cellular DNA or histones (epigenome) are known to play an important role in the etiology of diseases [154]. The epigenome plays a pivotal role in the regulation of chromatin activity and therefore affect DNA repair and gene expression [152]. Epigenomic alterations have been established in obesity, diabetes and cancer [154–156]. Adequate evidence exists, that epigenetic dysregulations have been implicated in the pathogenesis of oral and oropharyngeal cancers [157–161]; hence it is plausible that epigenomic analyses would provide better insight into oral carcinogenesis.

Microbiomics Bacterial genetics of the human oral microbiota has been interrogated using a combination of transcriptomics and microbiomics techniques [162–164].

This techniques is highly beneficial for understanding infective dental pathologies such as periodontitis, osteomyelitis and caries; and can be potentially applied to non-infective diseases such as cancer as well [165, 166].

Proteomics Mass spectrometry-based quantitative proteomics analysis has revealed an enhanced interferon-related signaling pathway for oral cancer cells in vitro, using labeled-mass spectrometry coupled to a high performance liquid chromatography (HPLC) system [167]. Such findings required further study into the significance of interferon in the pathogenesis of oral squamous cell carcinoma and may serve as a basis for development of targeted therapies and potential biomarkers for oral cancer.

Lipidomics One of the major breakthroughs in the field of lipidomics that could potentially revolutionize the field of surgical oral pathology is the fast, real-time mass spectrometry based identification of surgical margin of tissues intraoperatively with the use of the i-knife [168]. This technique diagnosed cancer margin accurately in a more reliable and unbiased manner using lipidomic signatures that differentiated between tumor and normal areas [168]. This could potentially eliminate the intraoperative waiting time while sending surgical specimen for frozen section tumor margin analysis.

Metabolomics The science of metabolomics looks at the differential signature of metabolites in biological pathways in a high throughput manner. Tiziani et al. [169] identified metabolomics signatures for early diagnosis of oral cancers using ¹H-nuclear magnetic resonance (NMR) spectroscopy methods. This method could potentially be used for routine early clinical diagnosis of various oral cancers. Recently, the push for reliable non-invasive timely diagnosis of cancer has directed research interest in the area of exhaled breath analysis for early detection. Breathomics is a branch of metabolomics that measures the total amount of volatile organic compounds (VOCs) in exhaled air [170]. Volatile and nonvolatile organic components of the exhaled air are relevant indicator of metabolic status for clinical diagnosis and monitoring purposes [171]. Various metabolic processes in the body produce VOCs that are released into the blood and transported to the lung where they are passed to the airway and exhaled. Acquisition and measurement of unique VOCs that may indicate occurrence of chronic inflammation and/or oxidative stress are potential biomarkers for early cancer detection [172]. This may be a plausible non-invasive early-stage cancer screening tool and may be potentially applied to the detection of head and neck cancers.

Ancillary tools for omics based technology

Nanotechnology Nanotechnology is an emerging, highly beneficial, multidisciplinary area of research that deals with atomic and molecular levels of matter. Some clinical trials are currently directed at demonstrating the therapeutic efficacy of nanomaterials against chronic diseases such as cancer [173]. Today, nanomedicine plays a significant role in diagnostic sciences, gene therapy, drug delivery systems, as well as in screening of populations [174, 175]. Both the field of medicine and dentistry have benefitted reasonably from therapeutic and diagnostic applications of nanomaterials [176]. Several forms of nanomaterials and nanotechnology methods have been used for the diagnosis and treatment of oral cancer. A few such modalities that have benefitted the field of oral pathology and oral cancer diagnosis and treatment are Surface Enhanced Raman Spectroscopy (SERS) [177, 178], composite organic–inorganic nanoparticles (COIN) [179, 180] and quantum dots (QD) [177, 181]. For example, Raman difference spectroscopy has been demonstrated as a non-invasive method for oral cancer diagnosis [182]. There is no doubt however; that these and many other nanotechnology approaches would continue to enhance the application omics approaches to personalized medicine and oral pathology.

Molecular imaging Molecular imaging is a highly beneficial tool with the capacity to improve every aspects of cancer care. It is an in vivo imaging-based characterization and measurement of the key biomolecules and molecular events that are basic to the malignant or aberrant state [183]. Prior to the emergence of molecular imaging, a number of “gold standard” scientific approaches (such as ViziLite, VELscope, Trimira and OralCDx, etc.) aimed at oral lesion detection were fraught with inconsistencies during standard routine head and neck examinations [184–186]. However, the establishment of integrated MRI/PET has improved the consistency and effectiveness of earlier stage cancer detection [187]. Molecular imaging such as positron emission tomography (PET) often integrated with cross sectional imaging in the form of PET/computed tomography (PET/CT), PET/magnetic resonance imaging (MRI)/MR spectroscopic imaging (MRSI), as well as optical imaging; play a vital role in cancer detection, staging and assessment of treatment response. The optical imaging is mostly performed with the radiotracer ^{18}F -fluoro-2-deoxy-D-glucose [FDG], integrated with cross-sectional imaging in the form of PET/computed tomography (PET/CT) [188]. PET has been said to be the leading molecular imaging approach in a clinical environment [189–191]. PET imaging methods have been successful in both staging of diverse cancers and assessment of response of tumors to therapy [192, 193]. Several authors have shown a sig-

nificantly higher level of sialic acid in oral cancer patients when compared to normal patients [194–196]. The recent discovery of molecular imaging-based individualized potential molecular tumor fingerprint has facilitated a rapid and effective development of theranostic drugs for novel treatment algorithms [197, 198]. In another study, the efficacy of fluorescence imaging using topically applied lectin-fluorophore conjugates as compared to conventional tissue autofluorescence in distinguishing tumor from normal tissues was also investigated [199]. The results revealed that the changes in glycosylation could differentiate normal from cancerous tissues in the oral cavity with high SNRs [199]. This is potentially a non-invasive screening method for premalignant and malignant oral mucosal tumors; and as a method for defining surgical margins and monitoring cellular changes over time. To further validate this approach for oral cancer screening, in vivo testing in a larger clinical cohort is needed. Not least, Nanobodies have also been considered as highly beneficial agent in molecular imaging of cancers, due to its rapid accumulation in tumors, homogenous distribution; efficient blood clearance, high specificity, safety, high tumor signal-to-background ratios; as well as ease of conjugation to several kinds of imaging techniques [200].

Future molecular concepts Several advances have emerged in precision and personalized medicine which could potentially benefit the field of oral pathology vis-à-vis molecular oral cancer diagnostics and therapy. The advent of microfluidic technology [201, 202] has made it possible to establish a rapid multistage, multi-technique technology known as Lab-on a-chip [202, 203]. This has permitted a high turnover of requested laboratory investigations during clinical diagnosis and therapy. This technology and those mentioned above have rapidly improved the development of point-of-care (POC) diagnostic tools [204–206]. These developments may have potential applications for oral pathology and cancer management. It is also clear that stem cell science has improved the field of dentistry and oral pathology. Somatic stem cells can be harvested from patients and reprogrammed to form patient-specific induced pluripotent stem (iPS) cells [207]. These iPS cells can be used for recombination and regenerative production of maxillofacial structures for transplantation and maxillofacial structure reconstruction [207]. On the other hand, subpopulations of cancer stem cells have been previously identified in head and neck cancers, by the application of stem cell science [208]. Such in-depth knowledge can also provide future stem cell-based targeted therapies against head and neck cancers [209]. Quantum medicine approaches such as quantum tunneling [210] has been previously used in understanding genetic mutations in cancers [211]. A quantum mechani-

cal approach is now being considered in the understanding of the evolution of cancers [211, 212]. There is no doubt that these emerging molecular concepts are poised to play a major role in oral pathology and cancer diagnosis; as well as therapies in the foreseeable future.

Recommendations

Considering the immense potential benefits of omics based approaches in the field of oral pathology and cancer diagnosis in developing African regions, the authors make the following recommendations:

- Government focus should be directed at funding Infrastructure (bridging the record gap); funding researchers and supporting research training (bridging the knowledge gap).
- As custodians of various tissue specimens, pathologists must take the lead (and must not be passive) in the application of omics based molecular techniques to routine diagnostic services. Advanced certification and annual remedial courses are also recommended.
- With favorable health policy change, omics based molecular approaches should be integrated into routine clinical practice, taking dutiful quality assurance (internal and external) measures.
- There should be private sector/non-governmental organization (NGO) participation to make the task of integration of omics into oral pathology effective.
- Reimbursement policy for oral pathologist who are willing to practice omics science must be favorable.
- Legislative initiative must be available to pass this concept into law.
- Scarce resources must be maximized (using mobile phones, internet, etc. to improve the practice of omics based approaches in oral pathology),
- Viable collaborative team science established (sharing ideas, research, equipment and meetings) must be established locally, regionally, continentally and globally.
- Research and Educational Networks (RENs) must be established using a trans/inter/multidisciplinary approach
- Omics-based science and personalized medicine topics should be integrated into the undergraduate and postgraduate medical/dental training curriculum
- There are many freely available online platforms that tremendously facilitate omics based techniques, such as the Gene Expression Omnibus (GEO) [213]; National Center for Biotechnology Information (NCBI) [214]; and The Cancer Genome Atlas (TCGA) [215]. Such platforms offer great

opportunities to develop knowledge in the omics field and researchers should be well enlightened about this.

Conclusion

In the light of the aforementioned recommendations and the tremendous burden of cancer in Africa, healthcare goals needs to capture the most reliable and cost effective methods for screening and early diagnosis of disease. It is unfortunate that despite the fact that up to 80% of the burden of cancer is found in the low and middle income countries (LMIC), it only receives about 5% of the global spending on cancer [216]. Africa has to piggy-back and emulate already existing transformative “training-the-trainer” systems in the Western world such as the: Training Residents in Genomics program (TRIG) and the Resident in Service Examination (RISE) practiced in the Americas and Western Europe [217, 218]. These programs exposes trainees to hands-on omics based molecular approaches during their residency program; and thus increases their confidence in requesting for and interpretation of such investigations. Considering that the cost of genomics investigation is on the decline and that we have entered into the \$1000 genome era [219, 220], the pertinent question for African oral pathologists is “are you ready for a genome-related clinical visits (with respect to their genetic risk for oral pathologies) by patients?” It is plausible that future histopathological reports would proceed beyond classic histological findings to morpho-molecular findings [218]; and a good knowledge of omics based molecular techniques is a *sine qua non* for an astute diagnostician. Emphasis should be placed on the multimodality approaches for omics based diagnostic oral oncological practices. Although all these techniques improve our knowledge of disease biology in an in-depth manner, they are most likely to play an adjunctive/supportive role rather than replacing existing pathological techniques in its application for improving detection and prognostic evaluation of head and neck cancer.

Abbreviations

B.C: before christ; CGH: comparative genomic hybridization; COIN: composite organic-inorganic nanoparticles; CT: computed tomography; DNA: deoxyribonucleic acid; ELISA: enzyme-linked immunosorbent assay; FDG: ¹⁸F-fluoro-2-deoxy-D-glucose; FISH: fluorescent in situ hybridization; GWAS: genome-wide association studies; H&E: hematoxylin and eosin; HPLC: high performance liquid chromatography; HPV: human papilloma virus; iPS: induced pluripotent stem; LMIC: low and middle income countries; MRI: magnetic resonance imaging; MRSI: magnetic resonance spectroscopic imaging; MSI: microsatellite instability; NGO: non-governmental organization; NGS: next generation sequencing; NMR: nuclear magnetic resonance; PET: point-of-care; QD: quantum dot; REN: research and educational network; RISE: resident in-service examination; RNA: ribonucleic acid; SERS: surface enhanced Raman spectroscopy; SNR: signal-to-noise ratio; TRIG: training residents in genomics; VOC: volatile organic compounds.

Authors' contributions

HAA conceptualized, designed, prepared and critically revised the manuscript and figure. OOS, AOA, SAJ, and AB were involved in the design, and critical intellectual revision of the paper. All authors were involved in preparing the manuscript and had final approval of the submitted and published versions. All authors read and approved the final manuscript.

Author details

¹ Department of Oral and Maxillofacial Pathology, Faculty of Dentistry, University of the Western Cape and Tygerberg Hospital, Cape Town, South Africa. ² International Centre for Genetic Engineering and Biotechnology, Cape Town, South Africa. ³ Division of Dermatology, Department of Medicine, Faculty of Health Sciences and Groote Schuur Hospital, University of Cape Town, Cape Town, South Africa. ⁴ Department of Oral Maxillo-facial Surgery and Oral Pathology, Obafemi Awolowo University, Ile-Ife, Nigeria. ⁵ Division of Health Sciences Education, Faculty of Health Sciences, University of the Free State, Bloemfontein, South Africa. ⁶ Department of Anatomical Sciences, Faculty of Health Sciences, Walter Sisulu University, Mthatha, Eastern Cape, South Africa. ⁷ Department of Oral Pathology, Radiology and Medicine, University of Iowa, Iowa City, IA, USA.

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Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

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Consent for publication

All authors have given consent for publication.

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